2.4.5 REACTOR CATEGORY AND COMMON ACTIVITIES

The alternatives under the Reactor Category considered in this PEIS would convert surplus Pu to MOX fuel for use in reactors. The irradiated MOX fuel would reduce the proliferation risks of the Pu material, and the reactors would generate electricity. The spent nuclear fuel generated from using the MOX fuel would be sent to an HLW repository or, if a foreign reactor is used, disposed of in a foreign spent fuel program.

These reactor alternatives include the following:

- Existing LWRs
- Partially Completed LWRs
- Evolutionary LWRs
- CANDU Reactors

Before surplus Pu can be used as reactor fuel, a conversion process is required to transform the Pu, in its various forms, into MOX fuel. The following common supporting facilities are required to process Pu, in its current forms, into MOX fuel:

- Pit disassembly/conversion facility
- Pu conversion facility
- MOX fuel fabrication facility

Under the various Reactor Alternatives, surplus Pu would be removed from storage, processed through the pit disassembly/conversion facility or Pu conversion facility, transported to the MOX fuel fabrication facility, converted into a MOX fuel, transported to the reactor site, and used as fuel for the reactor.

The Storage and Disposition PEIS addresses the disposition of surplus Pu. In the TSR PEIS (final version issued October 1995), there is an option for a multipurpose reactor that could produce tritium, use Pu in reactor fuel, and generate revenue through the production of electricity. Environmental analysis of the multipurpose reactor is included in the TSR PEIS. On December 6, 1995, the Secretary of Energy made the decision (60 FR 63878) that the future source of tritium would either be from a purchased reactor or irradiation in a commercial reactor or the accelerator production of tritium. The multipurpose reactor was preserved as an option for future consideration. DOE is also evaluating the operation of the FFTF at Hanford for its possible role as a multipurpose reactor in meeting future tritium requirements. Additional information can be found in Appendix N.

2.4.5.1 Mixed Oxide Fuel Fabrication

Mixed oxide fuel fabrication is common to all four reactor alternatives because each reactor would use Pu in the form of MOX fuel. In the 1970s, MOX fuel fabrication was conducted in a number of U.S. and foreign facilities on a laboratory or pilot line scale. However, today only the foreign MOX fuel fabrication programs continue. Proliferation concerns and unfavorable economics of Pu use resulted in a U.S. decision, in late 1970s, to defer indefinitely commercial reprocessing and recycling of the Pu produced in U.S. nuclear power programs. Consequently, MOX fuel fabrication facilities do not currently exist in the United States.

Converting surplus Pu into MOX fuel for use in a reactor would be consistent with U.S. nonproliferation policy since while the Pu is in the MOX fuel form it would be subject to high standards of safeguards and security and would be available for inspection by the IAEA. After use in a reactor, the Pu would meet the Spent Fuel Standard for proliferation resistance.

Because the United States does not have a MOX fuel fabrication facility or capability, a dedicated facility would likely have to be constructed or modified at a U.S. Government or existing commercial fuel fabricator's site. To provide MOX fuel until a domestic fuel fabrication plant is available, fuel for initial lead test assemblies and other MOX fuel may be produced by existing facilities in Europe on a short-term basis.

In accordance with the Preferred Alternative for surplus Pu disposition, the MOX fuel fabrication facility could be located at either Hanford, INEL, Pantex, or SRS. Further tiered NEPA review will be conducted to examine alternative locations, including new and existing facilities at these four sites, should the Preferred Alternative be selected at the ROD.

Facility Description. The MOX fuel fabrication facility would accept surplus Pu material in oxide form from the pit disassembly/conversion facility and the Pu conversion facility and fabricate mixed PuO_2-uranium dioxide (UO_2) fuel. The fabrication process would take PuO_2, purify it to meet MOX PuO_2 feed specifications, and blend it with UO_2 (this UO_2 may contain natural or depleted uranium) and any required burnable neutron absorbers. The MOX would be formed into pellets, loaded into fuel rods,[20] and assembled into fuel bundles. The facility would have storage capacity for approximately a 1-year supply of fuel bundles awaiting shipment to any of the various disposition reactors. Figure 2.4.5.1–1 presents a process flow diagram.

The total disturbed land area for the MOX fuel fabrication facility would be approximately 81 ha (200 acres), plus a 1.6-km (1-mi) wide buffer zone around the facility. All facility buildings would be located within a fenced area. A PA containing the fuel fabrication, waste management, receiving and storage, chemical storage, and cold support and utilities buildings would be surrounded by an appropriate perimeter security system. Within the PA, an MAA would connect the receiving and storage, fuel fabrication, and waste management buildings.

Figure 2.4.5.1–2 provides a facility site layout. The type of construction and the footprint area required for each building can be found in Appendix B. The mission description of these buildings follows.

Receiving and Storage Building. Process materials and supplies would be received and stored here. This building would house the Pu lag storage vault.

Fuel Fabrication Building. The MOX fuel fabrication processes would be housed here.

Waste Management Building. This building would process, temporarily store, ship, and provide control and accountability for all solid, liquid, contaminated, or uncontaminated generated wastes. The waste processes and handling areas would be segregated by waste form.

Cold Support and Utilities Building. This building would house HVAC, electrical, water, and natural gas distribution for the facility. It would also provide a machine shop and storage facilities for nonradioactive or uncontaminated materials.

General Administration and Security Building. This building would provide office and support space for the site.

Fire Station. This building would provide augmented support to the site (in addition to local services) for immediate response to fire and medical emergencies.

Chemical Storage Area. This area would provide space for chemical storage tanks that supply the buildings and processes in the PA.

[20] The term "rods" used herein means LWR rods or CANDU elements.

Utilities Area. This area would be the entrance and metering point for electrical, natural gas, and water supplies. The electrical substation, emergency generator(s), and associated switching equipment would be located in this area.

Facility Operations. Initial operations would begin 1 year before associated reactor operations using the MOX fuel. Based on these data, a campaign for the disposition of surplus Pu can be examined. As shown in Table 2.4.5.1–1, a Pu throughput of between 2.9 t/yr (3.2 tons/yr) and 5.0 t/yr (5.5 tons/yr) would be achievable. The average fraction of input weapons-grade Pu would determine the throughput required of the fuel fabrication facility and, consequently, facility size and environmental impact. The MOX fuel Pu fraction would range, depending on reactor type, between 2.2 and 6.8 percent of the heavy metal (uranium and Pu). Required throughput, depending on reactor type, would range between 52 t/yr (57 tons/yr) and 150 t/yr (165 tons/yr) heavy metal. Therefore, nominal MOX throughput would be 50 t/yr (55 tons/yr) heavy metal, and the bounding MOX throughput would be 150 t/yr (165 tons/yr) heavy metal. Expected annual utility consumption for facility operation, annual chemicals consumed during operation, and the number of personnel required during operation are provided in Appendix C.

Protection of special nuclear material requires an integrated program involving both material control and accountability. Safeguards and security systems would be designed to meet DOE, NRC, and, as applicable, IAEA requirements.

Estimated annual emissions released from the MOX fuel fabrication facility during operations are listed in Appendix F. These emissions would be made up of various gases used or otherwise generated as a result of activities involved in MOX fuel fabrication. All gaseous effluent streams coming from the facility would be thoroughly scrubbed or filtered to remove or reduce the amount of undesirable particulates before release. Estimates of annual wastes resulting from the MOX fuel fabrication facility are shown in Appendix E. No HLW would be generated during normal operations. A diagram of the water balance for the new MOX fuel fabrication facility is presented in Appendix D.

Construction. The construction of the MOX facility would require 6 years and have a peak annual employment of 475 construction workers. The primary constraint on this schedule is the coincident operation of the MOX fuel fabrication facility with that of the two to five dispositioning reactors and the availability of the PuO_2 stock. Additional land area required for construction is projected to be approximately 40 ha (99 acres). This provides

Table 2.4.5.1–1. Mixed Oxide Fuel Reactors Operations Assumptions

Reactor Type (3 to 5 LWRs required)	Average MOX Enrichment of Pu in Heavy Metal (percent)	Pu Throughput (t/yr)	MOX Throughput (t/yr of heavy metal)
Existing			
BWR-full MOX	3.0	3.0	98.8
PWR-full MOX	4.2	5.0	118.2
CANDU-reference MOX[a]	2.2	2.9	136.1
CANDU-CANFLEX MOX[a]	3.4	5.0	149.9
Evolutionary			
Large	6.8	3.5	52.2
Small	6.6	4.1	61.4

[a] CANDU-reference MOX utilizes a standard fuel bundle, whereas the CANFLEX-MOX option uses an alternate fuel design that would permit the use of higher Pu concentrations and result in a higher burn-up of the MOX fuel.

Source: DOE 1996o; LANL 1996b.

for construction material laydown, warehousing, and temporary parking. Materials and resources consumed during construction of a new facility, and the number of construction personnel required, are presented in Appendix C. Total amounts of solid and liquid wastes generated during construction are given in Appendix E.

Waste Management. The solid and liquid nonhazardous wastes generated during construction would include concrete and steel construction waste materials and sanitary wastewater. The steel construction waste would be recycled as scrap metal before construction was completed. The remaining nonhazardous wastes generated during construction would be disposed of by the contractor as part of the construction project. Uncontaminated wastewater would be used for soil compaction and dust control, and excavated soil would be used for grading and site preparation. Non-hazardous wood, paper, and metal wastes would be shipped offsite to a commercial contractor for recycling. Hazardous wastes such as adhesives, oils, and solvent rags would be packaged in DOT-approved containers and shipped to offsite commercial RCRA-permitted treatment, storage, and disposal facilities. No soil contaminated with hazardous or radioactive constituents is expected to be generated during construction. However, if any were generated, it would be managed in accordance with site practice and all Federal and State standards.

Operation of a new MOX fuel fabrication facility would generate TRU, low-level, hazardous, mixed, and nonhazardous wastes. The conceptual design includes waste management facilities that would treat and package all waste generated into forms that would enable staging and disposal in accordance with RCRA and other applicable statutes. TRU and mixed TRU waste would be treated and packaged to meet the WIPP WAC. These wastes would be stored awaiting shipment to a Federal repository (assumed to be WIPP, depending on decisions resulting from the supplemental EIS for the proposed continued phased development of WIPP for disposal of TRU waste). LLW would be treated and packaged to meet the WAC of an onsite or offsite LLW disposal facility. The LLW treatment/disposal facilities that would be used would be consistent with decisions resulting from the Waste Management PEIS and NEPA reviews tiered from that PEIS. Mixed LLW would be treated and disposed of in accordance with the respective site treatment plan which was developed to comply with the *Federal Facility Compliance Act* of 1992, if applicable, and with decisions made pursuant to the Waste Management PEIS and tiered NEPA reviews, if applicable. Hazardous wastes would be packaged in DOT-approved containers and shipped to RCRA-permitted treatment and disposal facilities. Liquid nonhazardous wastes, such as sanitary, utility, and process wastewater, would be treated and discharged in accordance with the site practice or reclaimed to use as makeup water when economically and/or environmentally desirable. Solid nonhazardous waste would be disposed of in permitted landfills and recycled as appropriate. Additional details can found in Section E.3.2.3.

Transportation. Transportation of Pu and associated wastes would be subject to government regulations and DOE Orders regarding safety and security. The facility would receive PuO_2 and send out completed MOX fuel bundles. Intersite shipment of Pu-bearing material would be by SST to minimize potential for diversion. For domestic MOX fuel fabrication, UO_2 feed stock would come from existing domestic commercial sources and would be shipped by approved commercial carriers. UO_2 feed stock for European MOX fuel fabrication would come from existing European sources. Appendix G presents intersite transportation data for input and output materials.

European Mixed Oxide Fuel Fabrication Facility. MOX fuel could be produced in existing European MOX fuel fabrication facilities. However, studies have shown that the Europeans are driving their MOX fuel fabrication capacity and projected MOX fuel demand towards a balance (DOE 1995c:1-7). In the near-term, European MOX fuel fabricators have excess capacity that could be applied to support weapons-Pu disposition. This excess capacity could support fabrication of lead test assemblies and possibly partial reloads or a few reload full cores. While the Europeans may be willing to expand their capacity to support surplus weapons-Pu disposition, the United States would likely have to pay a premium for such MOX fuel. In addition, because European MOX capacities and demand could unexpectedly change, resulting in the loss or gain of excess capacity, until contracts are signed for the fabrication of fuel from U.S. surplus-weapons Pu, the United States should not rely on excess European MOX fabrication capacity in the long term. Transportation risks associated with moving the Pu feed materials and the finished MOX fuel across the global commons are presented in Appendix G.

2.4.5.2 Existing Light Water Reactor Alternative

Under this alternative, surplus Pu would be removed from storage, processed through the pit disassembly/ conversion facility or the Pu conversion facility, packaged, transported to a MOX fuel fabrication facility, and converted to MOX fuel. The finished MOX fuel would be transported to three to five existing LWRs for use in lieu of conventional uranium reactor fuel. The reactors employed for domestic electric power generation are conventional LWRs that use water as a moderator and coolant. The two types of LWRs used are pressurized water reactors (PWRs) and boiling water reactors (BWRs). Approximately two-thirds of the operating power reactors in the United States are PWRs.

In accordance with the Preferred Alternative for surplus Pu disposition, three to five existing LWRs could be selected. This would occur only after negotiations between DOE and interested parties, and through a competitive procurement process. Further tiered NEPA review will be conducted to examine locations (as many as five sites or as few as one site) should the Preferred Alternative be selected at the ROD.

Facility Description. A sample of reactors from across the United States was compiled in order to generate generic operating characteristics for a commercial LWR, since no specific site or reactor has been selected. The sample was studied to determine valid, applicable characteristics that could be used to describe a generic reactor using MOX fuel. The sample includes eight operating high power (greater than 1,200 megawatt electric [MWe]) PWRs and four BWRs built after 1975. Characteristics of these 12 were felt to be representative of both reactor types, since none of the 12 experienced any unusual operating conditions over the operating period reviewed. Where possible, data was averaged for the 5-year period to smooth out unusually low or high values due to shutdowns for reasons other than normal refueling or maintenance activities.

Data for each reactor characteristic were taken for calendar years 1988 to 1992 (ORNL 1995b:A-5). Entries for all 12 plants were used to determine an average for each listed characteristic.

Nuclear power plants generally contain the four major components described below. Figure 2.4.5.2–1 depicts a typical LWR facility.

Reactor Building. This building houses the reactor vessel, the suppression pool (BWRs only), steam generators and pressurizers (PWRs only), pumps, and associated piping. BWRs generate steam directly within the reactor core and pass it through internal moisture separators and steam dryers before sending it to the turbine. In contrast, PWR reactor heat is transferred from the primary coolant to a secondary coolant loop that is at a lower pressure. Generated steam from the secondary loop then flows to the turbine.

All domestic nuclear power plants have containment structures as a major safety feature to prevent release of radionuclides in the event of an accident. BWR containments are composed of a suppression pool and dry well. PWRs have one of three types of containments structured: large, dry; subatmospheric; or ice condenser. Large, dry containments comprise approximately 80 percent of the PWR containment structures.

Turbine Building. This building houses the steam turbine and generator, condenser, waste heat rejection system, pumps, and equipment that support these systems.

Auxiliary Buildings. These buildings house support systems such as the ventilation system, emergency core cooling system, water treatment system, waste treatment system, fuel storage facilities, and plant control room. Also, the plant site contains a large switchyard.

Cooling Towers and Ponds. Water is used predominantly for cooling in nuclear power plants, and accordingly these facilities are designed to remove excess heat without dumping this heat directly into adjacent water bodies. The quantity of water used is a function of several factors, including the capacity rating of the plant and the increase in cooling water temperature from intake to discharge. Therefore, the larger the plant, the greater the quantity of waste heat to be dissipated and the greater the quantity of cooling water required. In addition, the quantity of water used is a function of the type of cooling system.

Approximately half of the operating power reactors use "closed-cycle" cooling systems as opposed to "once-through" cooling systems. In closed-cycle systems, waste heat is removed by dissipation to the atmosphere, usually through cooling towers. Several types of closed-cycle cooling systems are currently in use. These systems consist of either natural or mechanical draft cooling towers, cooling ponds, cooling lakes, or cooling canals. Most of the water used for cooling is not returned to a water source because the predominant cooling mechanism associated with closed-cycle systems is evaporation.

In addition to removing waste heat, closed-cycle systems provide cooling for service water and auxiliary cooling water systems. At closed-cycle cooling sites, the additional water needed for source water and auxiliary cooling water systems is usually less than 5 percent per year of that needed for waste heat cooling.

In a once-through cooling system, circulating water is drawn from an adjacent body of water (such as a lake), passed through cooling tubes, and returned to the same body of water at a higher temperature. The volume of water required for service and auxiliary systems is usually less than 15 percent of the volume required for waste heat cooling at once-through cooling sites. Some systems are augmented with helper cooling towers that reduce the temperature of the water released. Waste heat is then dissipated in the receiving water body.

The water intake and discharge structures accommodate the source water body and minimize impacts to the aquatic ecosystem in both cooling systems. The intake structures are generally located along the shoreline of the body of water and equipped with fish protection devices. The discharge structures are generally of the jet or diffuser outfall type and are designed to promote rapid mixing of the effluent stream with the receiving body of water. Chemicals used for corrosion control and other water treatment purposes are also mixed with the cooling water and then discharged from the system.

Some nuclear power plants use groundwater as a source of makeup or potable water in addition to surface water sources. Other existing LWR sites operate dewatering systems that intentionally lower the groundwater table in the vicinity of building foundations either through pumping or a system of drains.

Facility Operations. Three to five existing LWRs would be operated to achieve 3 to 5 t/yr (3.3 to 5.5 tons/yr) throughput for disposition of surplus Pu and simultaneous production of electric power. No attempt was made to characterize the optimum reactor deployment approach. The data presented and analyzed in this PEIS is representative of reactor operations using full MOX fuel cores. The actual core loading for individual reactors will be determined as part of business decisions that follow the ROD. The MOX fuel Pu fraction would range, with reactor type, between 3 and 4.2 percent. MOX throughput depends on reactor type and ranges between 99 t/yr (109 tons/yr) and 118 t/yr (130 tons/yr) heavy metal (uranium and Pu). After discharge from the reactor, the spent MOX fuel assemblies would be stored at the reactor site for up to 10 years before further disposition. A typical LWR facility fuel cycle is depicted in Figure 2.4.5.2–2.

Construction. Major construction activities associated with the existing domestic LWRs that could be selected for this alternative have been completed. The use of MOX fuel in these reactors may require an internal modification to reactor site fuel receiving and storage buildings to properly secure the MOX fuel prior to its use. No significant additional land would be required for this construction.

Waste Management. During the fission process, radioactive products build up within the fuel. Virtually all of these products are contained within the fuel. However, a small fraction of the fission products can escape the fuel and contaminate the reactor coolant. The primary system coolant also contains radioactive contaminants as a result of neutron activation. The radioactivity found in the LWR coolant is the source of gaseous effluent, liquid effluent, and solid radioactive wastes. The following describes the basic design and operation of PWR and BWR radioactive waste treatment systems.

Gaseous Radioactive Effluents. For BWRs, an air ejector is the primary source of routine radioactive gaseous effluents released to the atmosphere. Air ejectors are used to remove noncondensable gases from the coolant to improve power conversion efficiency and reduce gaseous and vapor leakages to the atmosphere. After monitoring and filtering, the leakages are discharged to the atmosphere by the building ventilation system. The offgas treatment systems collect noncondensable gases and vapors exhausted from the condenser by the air ejectors. These offgases are then processed through a series of delay systems and filters to remove airborne radioactive particulates and halogens, thereby minimizing the quantities of radionuclides that might be released to the atmosphere. Building ventilation system exhausts are another source of gaseous radioactive emissions for BWRs.

The PWRs have three primary sources of gaseous radioactive effluents: discharges from the gaseous effluent management system, discharges associated with the exhaust of noncondensable gases from the main condenser (if a primary-to-secondary system leak exists), and radioactive gaseous discharges from the building ventilation exhaust. This includes discharges from the reactor building, the reactor auxiliary building, and the fuel-handling building.

The gaseous effluent management system collects fission products. These fission products consist mainly of inert gases that migrate to the primary coolant. A small portion of the primary coolant flow is continually diverted to the primary coolant purification, volume, and chemical control system to remove contaminants and adjust the coolant chemical makeup and volume. During this process, noncondensable gases are stripped and routed to the gaseous effluent management system, which consists of a series of gas storage tanks. The storage

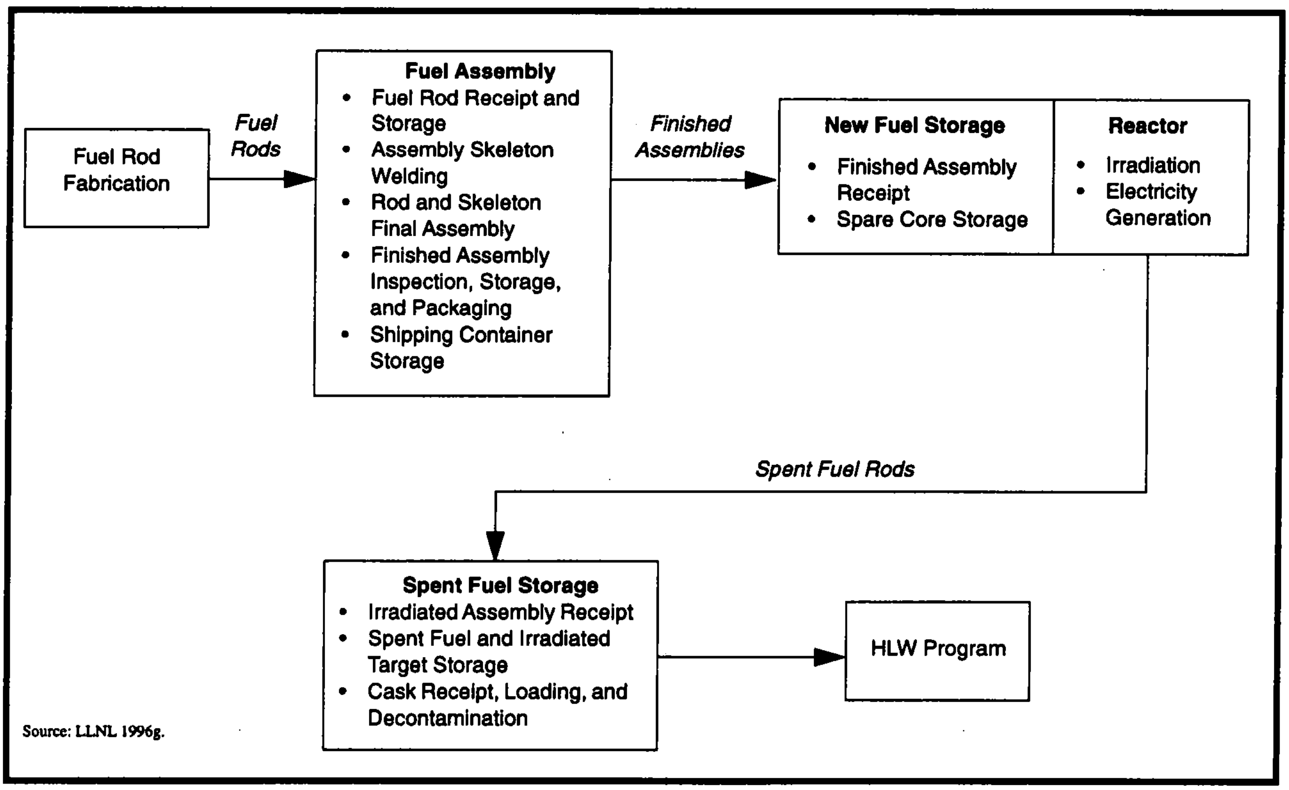

Figure 2.4.5.2–2. Representative Existing Light Water Reactor Fuel Cycle.

tanks allow the short half-life radioactive gases to decay, releasing only relatively small quantities of long half-life radionuclides to the atmosphere. In addition, some PWRs use charcoal delay systems rather than gas holdup tanks. Expected gaseous radioactive effluent is shown in Appendix F.

Liquid Radioactive Effluents. The source of liquid radioactive effluents in LWRs is radionuclide contaminants in the primary coolant. The specific sources, their mode of collection and treatment, and the types and quantities of liquid radioactive effluents released to the environment are similar in BWRs and PWRs. The following discussion applies to both BWRs and PWRs, with distinctions made only when important differences exist.

Liquid effluents from LWRs may be classified in the following categories: clean wastes, dirty wastes, detergent wastes, turbine building floor drain water (BWRs only), and steam generator blowdown (PWRs only). Clean wastes include all liquid effluents with normally low conductivity and variable radioactivity content. These wastes are collected from equipment leaks and drains, valve and pump seal leakoffs not collected in the reactor coolant drain tank, and other leakage sources.

Dirty wastes include all liquid effluents with moderate conductivity and variable radioactivity content that, after processing, may be used as reactor coolant makeup water. Dirty wastes consist of liquid effluents collected in the containment building sump, auxiliary building sumps and drains, laboratory drains, sample station drains, and other miscellaneous floor drains. Detergent wastes consist primarily of laundry wastes and personnel and equipment decontamination wastes. These wastes normally have a low radioactivity content. Water from the turbine building floor drain usually has high-conductivity and low-radionuclide content. In PWRs, steam generator blowdown can contain relatively high concentrations of radionuclides, depending on the amount of primary-to-secondary leakage present. Following treatment, the water may be reused or discharged.

Each of these liquid effluent sources receives varying degrees of and different types of treatment before storage for reuse. Some treated effluents can also be discharged by a site to the environment under the National Pollutant Discharge Elimination System (NPDES) permit. The extent and types of treatment depend on the chemical and radionuclide content of the effluent. To increase the efficiency of processing, effluents of similar characteristics are batched before treatment.

Operating plants have steadily increased the degree of treatment and storage of liquid radioactive effluents. In addition, extensive recycling of steam generator blowdown in PWRs is now common, and secondary side wastewater is routinely treated. Also, the systems used to treat effluents may be augmented with the use of commercial mobile treatment systems. As a result, radionuclide releases in liquid effluent from LWRs have generally declined. Expected liquid radioactive effluent is shown in Appendix E.

Solid Radioactive Waste. Nuclear power plants generate solid LLW through the removal of radionuclides from liquid waste streams, filtration of airborne gaseous emissions, and removal of contaminated material from various reactor areas. Concentrated liquids, filter sludges, waste oils, and other liquid sources are segregated by type and then flushed to storage tanks. They are stabilized for packaging in a solid form by dewatering, then slurried into 208-l (55-gal) steel drums and stored onsite in shielded buildings or other facilities until suitable for offsite disposal. These buildings usually contain volume reduction facilities to reduce LLW for offsite disposal.

High-efficiency particulate air (HEPA) filters are used to remove radioactive material from gaseous plant effluents. These filters are compacted in volume reduction facilities. The material is then disposed of as solid radioactive waste.

Solid LLW consists of contaminated protective clothing, paper, rags, glassware, compactible and noncompactible trash, and non-fuel-irradiated reactor components and equipment. Most of this waste comes from plant modifications and routine maintenance activities. Additional sources include tools and other materials contaminated from use in the reactor environment. Compacted dry radioactive waste is the largest single form of

LLW generated by nuclear plants, and it comprises one-half the total average annual volumes from PWRs and one-third of total average annual volumes from BWRs. Expected waste generated is shown in Appendix E.

Spent Nuclear Fuel. The formation of fission products and actinides when nuclear fuel is irradiated in reactors produces spent fuel. After it is removed from reactors, spent fuel is stored in racks in storage pools to isolate it and to allow the fuel to cool (that is, lose some radioactivity due to decay of the short-lived radioisotopes). Delays in siting a permanent repository, as well as the continual filling of spent fuel pools, have led utilities to seek other storage solutions. These solutions include high-density storage within the existing storage pools, aboveground dry storage, longer fuel burnup, and shipment of spent fuel to other plants.

Efforts are underway to develop dry storage technologies. These technologies include casks, silos, dry wells, and vaults. The NRC has already licensed a number of casks for utilization by public utilities. Dry storage is used by about 5 percent of the operating sites. These facilities are simpler and more readily maintained than fuel pools. They offer a more stable means of storage, occupy relatively little land area (less than 0.2 ha [0.5 acres] in most cases), and offer important economic advantages. Spent fuel is required to be maintained in the spent fuel storage pool for up to 10 years to allow for sufficient cooling. The increased number of MOX spent fuel assemblies shown in Table 2.4.5.2–1 would therefore need to be held in an existing pool for this same amount of time. All the plants studied have sufficient pool capacity to accommodate additional assemblies resulting from use of MOX fuel.

Table 2.4.5.2–1. Existing Light Water Reactor Facility Additional Spent Fuel Generation/Storage Requirements

	Spent Fuel Assemblies	
	PWR	**BWR**
Typical LEU-fueled plant	48	127
Additional for MOX-fueled plant (average)	32	15

Source: ORNL 1995b.

Transportation. There are five types of radioactive material shipments: LLW transported from plants to disposal facilities, LLW shipped to offsite facilities for volume reduction, nuclear fuel shipments from fuel fabrication facilities to plants for loading into reactors (which occurs on a 12- to 18-month cycle), spent fuel shipments from the storage pool at the reactor site to a repository (would only occur after a repository is recommended, approved, and licensed pursuant to the NWPA, and the particular fuel is accepted by the repository), and spent fuel shipments to other nuclear power plants with available storage space (an infrequent occurrence usually limited to plants owned by the same utility).

Waste packaging protects workers and the public from exposure during radioactive material transport. Operation restrictions on transport vehicles, ambient radiation monitoring, imposition of licensing standards (which ensure proper waste certification by testing and analysis of packages), waste solidification, and training of emergency personnel are also used.

A typical PWR creates approximately 44 shipments of LLW per year, while an average BWR makes 104 shipments per year. The majority of the LLW is shipped to disposal facilities by flatbed truck. These shipments are typically packaged in 208-l drums or other Type A containers. These containers must maintain sufficient shielding to limit radiation exposure to handling personnel and do not allow for release of radioactive material under normal transportation conditions.

Fresh MOX fuel is substantially more radioactive than fresh LEU fuel and would be shipped in Type B packages designed and certified for the shipment of unirradiated MOX fuel. One such package is Model No. MO-1 (Certificate No. 9069). Because the quantity of Pu in the fuel is greater than 6 kg (13.2 lbs), the unirradiated

MOX fuel package would be transported within an SST. A variant for this alternative is to use an existing European MOX fuel fabrication facility on a short-term basis. Pu feed material for the European facility would be transported across the global commons to the fabrication site. Similarly, the finished MOX fuel would be transported back to the United States across the global commons. An analysis of the transportation risks associated with this variant are presented in Appendix G.

After discharge from the reactor, spent fuel is placed in the spent fuel storage pool and allowed to cool until it can be sent to permanent disposal. Because of the limited size of spent fuel pools, some utilities have resorted to shipment of spent fuel between different reactors (usually within the same utility). For shipment, spent fuel is placed in Type B packages (called casks), and shipped by either truck or rail. Spent fuel shipping casks are very robust, and are designed to retain the highly radioactive contents under both normal and accident conditions.

A number of truck and rail casks are available for shipment of LEU spent fuel. Shipment of MOX spent fuel may require that each cask design be re-evaluated, and the NRC certificate may need to be amended to address the MOX spent fuel characteristics. Among the many casks designed for spent fuel, truck casks in the 23-t (25-tons) to 36-t (40-tons) range, such as (1) NAC-LWT (for one PWR or two BWR assemblies), (2) GA-4 (for four PWR assemblies), and (3) the GA-9 (for nine BWR assemblies), could be utilized.

2.4.5.3 Partially Completed Light Water Reactor Alternative

Under this alternative, commercial domestic LWRs on which construction has been halted would be completed and operated for disposition. The completed reactors would use MOX fuel in lieu of conventional LEU fuel. The characteristics of these units would essentially be the same as those of contemporary operating commercial LWRs discussed in Section 2.4.5.2. There are seven partially completed commercial LWRs located at four sites in the continental United States. The Bellefonte Nuclear Plant has been selected for study as a representative site for this alternative. As was stated for the Existing LWR Alternative, before the surplus Pu can be used as reactor fuel, a conversion process would be required to transform the Pu, in its various forms, into a usable form. Pit disassembly/conversion, Pu conversion, and MOX fuel fabrication facilities would be required to process the Pu into MOX fuel. All requirements shown in this section are in addition to those previously described for the pit disassembly/conversion, Pu conversion, and MOX fuel fabrication facilities. Since the reactors that would use the MOX fuel are in addition to existing commercial reactors, these partially completed reactors would create an additional amount of spent fuel to be added to the existing disposal requirements for uranium-based fuels.

In accordance with the Preferred Alternative for surplus Pu disposition, two partially completed LWRs could be selected. This would occur only after negotiations between DOE and interested parties, and through a competitive procurement process. Further tiered NEPA review will be conducted to examine locations should this option of the Preferred Alternative be selected at the ROD.

Facility Description. The partially completed LWRs contain the same four major components described in Section 2.4.5.2: the reactor building, the turbine building, auxiliary buildings, and cooling towers or ponds. A representative partially completed reactor site layout is depicted in Figure 2.4.5.3–1.

Facility Operations. Partially completed reactor facility operations would be generally the same as those described in Section 2.4.5.2. In this alternative, two partially completed reactors would be operated with an average MOX throughput of 68 t/yr (75 tons/yr) heavy metal.

Construction. Construction of two partially completed reactors would have to be completed to satisfy requirements under this alternative. Appendix C contains resources and personnel requirements necessary to complete construction of the typical pair of reactors. The construction of the partially completed LWR facility would require 7 years and have a peak annual employment of approximately 2,300 construction workers.

Waste Management. The solid and liquid nonhazardous wastes generated during construction would include concrete and steel construction waste materials and sanitary wastewater. The remaining nonhazardous wastes generated during construction would be disposed of as part of the construction project by the contractor. Uncontaminated wastewater could be used for soil compaction and dust control, and excavated soil would be used for grading and site preparation. Wood, paper, and metal wastes would be shipped offsite to a commercial contractor for recycling. Hazardous wastes generated during construction would consist of materials such as waste adhesives, oils, cleaning fluids, solvents, and coatings. Hazardous waste would be packaged in DOT-approved containers and shipped offsite to commercial RCRA-permitted treatment, storage, and disposal facilities. No radioactive waste would be generated during construction. Waste management requirements for operation are the same as those discussed in Section 2.4.5.2. Appendix F shows reactor average annual emissions during the peak construction year, respectively.

Transportation. Transportation requirements for the partially completed LWRs are the same as those discussed in Section 2.4.5.2.

2.4.5.4 Evolutionary Light Water Reactor Alternative

Evolutionary LWRs would be designed for the purposes of surplus Pu disposition and simultaneous production of electric power. As for the Existing LWR and Partially Completed LWR Alternatives, before the surplus Pu can be used as reactor fuel, a conversion process is required to transform the Pu, in its various forms, into a usable form. Pit disassembly/conversion, Pu conversion, and MOX fuel fabrication facilities would be required to convert the Pu into MOX fuel. Each fuel assembly loaded into a reactor would reside in the reactor between 4 and 5.4 years, during which time the reactor would be at power 75 percent of the time. After discharge from the reactor, the spent fuel assemblies would be stored at the reactor site for up to 10 years before further disposition. All requirements in this section are in addition to those previously described for the pit disassembly/ conversion, Pu conversion, and MOX fuel fabrication facilities. Since the MOX-burning evolutionary reactors would be in addition to existing commercial reactors, these evolutionary reactors would create an additional amount of spent fuel to be added to the existing disposal requirement for uranium-based fuels.

Facility Description. Two evolutionary LWR design approaches, based on rated power (large and small reactor, designated large evolutionary LWR and small evolutionary LWR in the following discussion), are under consideration. There are three large evolutionary LWR designs: an approximately 1,400-MWe PWR, an approximately 1,250-MWe PWR, and an approximately 1,300-MWe BWR. A small, evolutionary LWR, approximately 600-MWe PWR, is also under consideration. For any design, an evolutionary LWR facility would consist of the following major components: the reactor, interim spent fuel storage, power conversion facility, and waste treatment facility. The planned Pu disposition campaign would require a minimum of two large evolutionary LWRs or four small evolutionary LWRs. The total disturbed land area for the evolutionary LWR operating facility would be approximately 138 ha (340 acres). In addition, a 1.6-km (1-mi) wide buffer zone around the facility may be required, depending on NRC licensing requirements. Figure 2.4.5.4–1 depicts a typical evolutionary LWR facility site plan. The major components of an evolutionary LWR facility are described below.

Reactor. The individual reactors would be an improved version of existing commercial electric power generating reactors using ordinary (light) water as both the moderator and coolant. The core, contained within a steel pressure vessel, would be composed of bundles of fuel rods. The fuel rods would consist of MOX fuel. The evolutionary LWR facility fuel cycle is depicted in Figure 2.4.5.4–2.

The cooling system selected, wet or dry, would depend on site characteristics. Both wet and dry cooling systems would use water as the heat exchange medium. Wet systems would use water towers and the evaporation process to carry off heat. Dry systems, designed for cold or high-humidity climates, would use water in closed nonevaporative cooling towers to remove heat by conduction to the atmosphere through heat exchangers. In moderate climates, fans would be added to the dry cooling towers to move air over the vanes of the heat exchangers. There would be some water loss through evaporation in a dry system, but significantly less than with a wet tower. Dry cooling towers would be used for the reactors at all dry sites. The use of wet cooling towers would be an option only for the power conversion facility and only when the facility would be located at a wet site.

Interim Spent Fuel Storage Facility. Spent fuel would be stored onsite in an underwater spent fuel storage pool.

Power Conversion Facility. This facility would contain a turbine generator, electrical equipment, control equipment, auxiliary systems, plant support systems, and other equipment.

Waste Treatment Facility. This facility would receive all solid, liquid, and gaseous radioactive waste for storage, treatment, and packaging for either release or disposal at an appropriate permanent waste disposal facility.

Facility Operations. As a minimum, two large reactors or four small reactors would be operated to achieve 3.5 t to 4.1 t/yr (3.6 to 4.5 tons/yr) throughput for the disposition of surplus Pu and the simultaneous production of electric power.

Construction. The construction of the evolutionary LWR would require 6 years and have a peak annual employment of 3,500 construction workers. Additional land area required for construction is projected to be approximately 146 ha (360 acres). This provides for construction material laydown, warehousing, and temporary parking. Appendix C contains resources and personnel requirements required for the construction phase.

Waste Management. The solid and liquid nonhazardous wastes generated during construction would include concrete and steel construction waste materials and sanitary wastewater. The remaining nonhazardous wastes generated during construction could be disposed of as part of the construction project by the contractor.

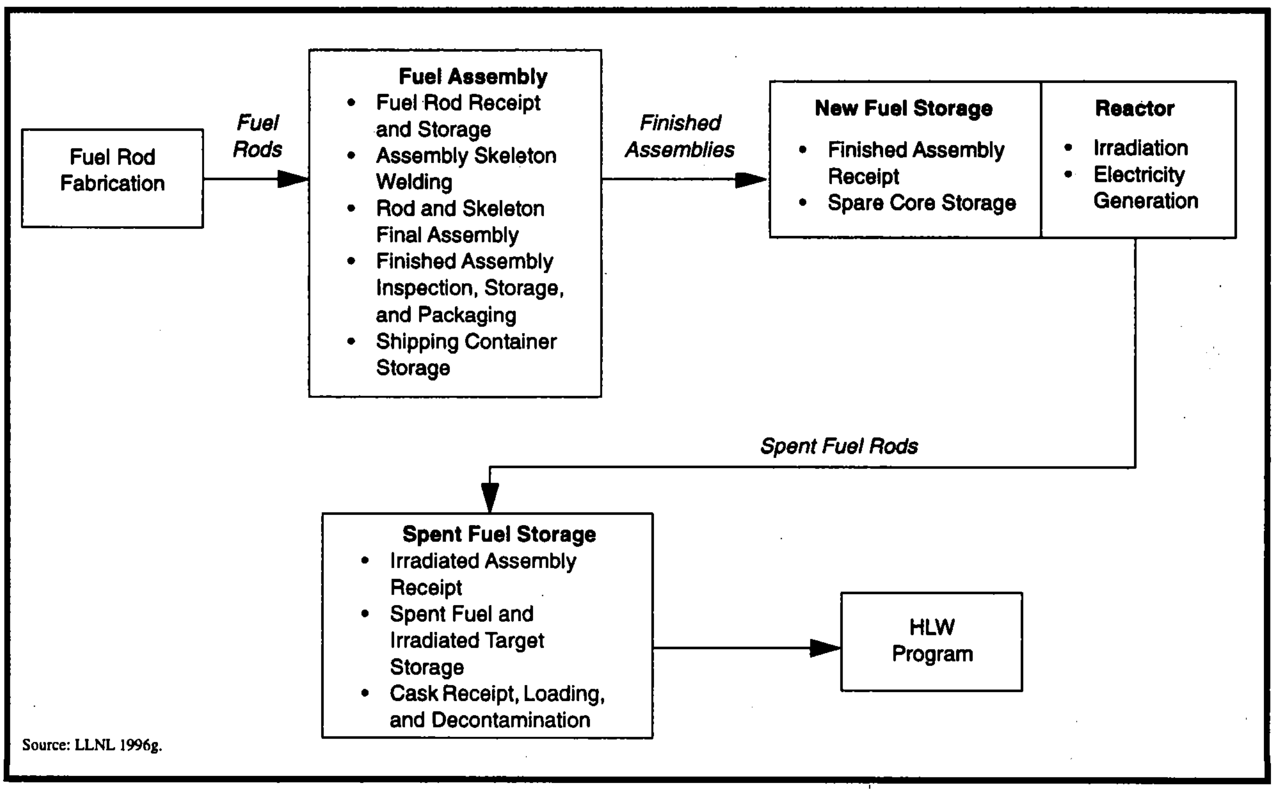

Figure 2.4.5.4–2. Representative Evolutionary Light Water Reactor Fuel Cycle.

Uncontaminated wastewater would be used for soil compaction and dust control, and excavated soil would be used for grading and site preparation. Wood, paper, and metal wastes would be shipped offsite to a commercial contractor for recycling. Hazardous wastes generated during construction would consist of materials such as waste adhesives, oils, cleaning fluids, solvents, and coatings. Hazardous waste would be packaged in DOT-approved containers and shipped offsite to commercial RCRA-permitted treatment, storage, and disposal facilities. No radioactive waste would be generated during construction.

The evolutionary reactor design considers and incorporates waste minimization and pollution prevention. Segregation of activities that generate radioactive and hazardous wastes would be employed, where possible, to avoid the generation of mixed wastes. Where applicable, treatment to separate radioactive and nonradioactive components would be performed to reduce the volume of mixed wastes and provide for cost-effective disposal or recycling. To facilitate waste minimization where possible, nonhazardous materials would be substituted for those materials that contribute to the generation of hazardous or mixed waste. Production processes would be configured with high priority given to minimization of waste production. Where possible, material from the waste streams would be treated to facilitate disposal as nonhazardous wastes. [Text deleted.]

Solid and liquid waste streams would be routed to the waste management system. Solid waste would be characterized and segregated into low-level, mixed, and hazardous wastes, then treated to forms suitable for disposal or storage within the facility. Liquid waste would be treated onsite to reduce hazardous/toxic and radioactive elements before discharge or transport. All fire sprinkler water discharged in process areas would be contained and treated as process wastewater.

Spent Nuclear Fuel. Fuel elements containing spent fuel would be stored for up to 3 years in water-cooled storage basins and up to 7 additional years in dry storage. The spent fuel pool would be equipped with an underwater canister loading system. Twelve spent fuel assemblies would be placed in fixed positions in a borated aluminum or stainless-steel basket for criticality safety. The basket would be contained in a canister whose lids are seal-welded in place. After the 3-year cooling period, the canisters would be drained, vacuum dried, and backfilled with helium through lid penetrations in preparation for dry storage. The canisters would be transferred in a cask to the interim spent fuel storage facility. At the storage facility, the canisters would be transferred into the final storage cask, which would be made of precast concrete and would hold one canister each. Casks would be placed on a concrete basemat. Periodic visual inspections of the canisters and the cask vents would be required. Periodic testing for helium leaks might also be required. Although the spent nuclear fuel is assumed to be stored at the reactor site for 3 to 10 years before further disposition, the facility design would have sufficient capacity to store the spent nuclear fuel for the life of the facility.

Transuranic Waste. The evolutionary LWRs would not generate any TRU waste.

Low-Level Waste. LLW would be generated by the operation of the reactor and support facilities. Process effluents would be temporarily stored in storage tanks before conversion into solid LLW that is suitable for disposal. The liquid effluent, after treatment, would be discharged through a permitted NPDES outfall. The bulk of the solid LLW would be generated in the reactor. Solid LLW would consist of contaminated equipment pieces, plastic sheeting, and protective clothing. This solid LLW would be compacted if appropriate and then disposed in a permitted onsite/offsite disposal facility.

Mixed Low-Level Waste. No liquid mixed LLW would be generated from operating the evolutionary LWR. Solid mixed LLW may originate from wipes laden with contaminated oils and hydraulic fluids. Mixed LLW would be stored in an onsite RCRA-permitted storage facility until treatment.

Hazardous Waste. Liquid hazardous waste would be generated from cleaning solvents, cutting oils, vacuum pump oils, film processing fluids, hydraulic fluids from mechanical equipment, antifreeze solutions, and paint. The cleaning solvent selected would be from a list of non-halogenated solvents. Liquid hazardous waste would be collected in DOT-approved containers and sent to an onsite hazardous waste accumulation area. The hazardous waste accumulation area would provide a 90-day staging capacity prior to shipment to an offsite commercial RCRA-permitted treatment, storage, and disposal facility. Solid hazardous waste would be generated from nonradioactive materials such as wipes contaminated with oils, lubricants, and cleaning solvents that are used for equipment outside the main processing units. After compaction, if appropriate, the solid hazardous waste would be packaged in DOT-approved containers and sent to a hazardous waste accumulation area for staging before shipment to an offsite commercial RCRA-permitted treatment, storage, and disposal facility.

Nonhazardous (Sanitary) Waste. Sewage wastewater would be treated in the sanitary wastewater treatment plant. Sewage wastewater would be kept separate from all industrial and process wastewaters and normally would contain no radioactive wastes from the reactor. The sewage wastewater would be routinely monitored for radioactive contaminants. The sludge would be disposed of in a permitted landfill. The treated effluent would be discharged through a permitted NPDES outfall (wet site) or recycled for cooling water makeup and other services (dry site). The treated effluent from the process wastewater treatment would be discharged to the river through an NPDES outfall. Other nonrecyclable, nonhazardous, solid sanitary, and industrial wastes would be compacted and disposed of in a permitted landfill.

Nonhazardous (Other) Waste. The evolutionary reactor design includes stormwater retention facilities with the necessary NPDES monitoring equipment. Rainfall within the LA and PA would be collected separately and routed to the stormwater collection ponds and then sampled and analyzed before discharge. If the runoff were contaminated, it would be treated in the radioactive waste treatment system. Runoff from the PPA may be discharged directly through an NPDES outfall into the natural drainage channels. Cooling tower blowdown would be treated and discharged to the outfall (wet site) or recycled for reuse (dry site). The treated effluent from the utility wastewater treatment would be discharged to the river through an NPDES outfall (wet site) or a natural drainage channel (dry site). All sludges would be disposed of in a permitted landfill.

Transportation. Transportation requirements for the evolutionary LWRs are the same as those discussed in Section 2.4.5.2.

2.4.5.5 Canadian Deuterium Uranium Reactor Alternative

Ontario Hydro operates 20 CANDU reactor units capable of using MOX fuel at five nuclear generating stations in the Province of Ontario. In addition, there is one CANDU reactor in the Province of Quebec and another CANDU reactor in New Brunswick. Under this alternative, surplus Pu would be removed from storage, processed through the pit disassembly/conversion or Pu conversion facility, packaged, transported to the MOX fuel fabrication facility, and converted into MOX fuel. The MOX fuel would be transported to and used in one or more CANDU reactors. The use of Canadian reactors would be subject to the approval, policies, and regulations of the Canadian Federal and Provincial governments.

Ontario Hydro Nuclear Bruce-A Generating Station has been identified as a reference facility by the Government of Canada and is used as a representative site for evaluation of the CANDU Reactor Alternative and the CANFLEX fuel bundle. The Ontario Hydro Nuclear Bruce-A Generating Station, containing four 769-MWe generating stations along with its four-unit sister station, Bruce-B, is located on Lake Huron about 300 km (186 mi) northeast of Detroit, Michigan.

Facility Description. The major components of a CANDU reactor are described below.

Reactor. An individual CANDU reactor has a horizontal, cylindrical, heavy-water filled, calandria tank containing 480 high-pressure fuel channel assemblies (also referred to as tubes) and reactivity control units. Heavy water, deuterium oxide (deuterium is a form of hydrogen with a neutron in its nucleus in addition to the proton of the hydrogen nucleus), is the neutron moderator and reflector. This entire assembly is contained in a light water-filled shield tank to form an integral structure that provides operational and shutdown shielding.

Power Conversion Facility. The turbine hall contains turbo-generators, electrical equipment, control equipment, auxiliary systems, plant support systems, and other equipment.

Vacuum Building. This facility is the focal point of the Negative Pressure Containment System.

Auxiliary Services Building. This facility houses supporting services for the Nuclear Generating Station.

Waste Treatment Facility. This facility would receive all spent fuel, solid, liquid, and gaseous radioactive waste for storage, treatment, and packaging for either release or disposal at an appropriate permanent waste disposal facility.

Facility Operations. The CANDU reactor MOX fuel cycle for CANDU fuel bundles in two CANDU reactors at the representative generating station would dispose of approximately 2.9 t/yr (3 tons/yr) of Pu based on a MOX throughput of 136 t/yr (150 tons/yr) heavy metal. Using the CANFLEX fuel design, four reactors would dispose of 5 t/yr Pu (5.5 tons/yr) based on a MOX throughput of 150 t/yr (165 tons/yr) heavy metal. The fuel cycle is depicted in Figure 2.4.5.5–1.

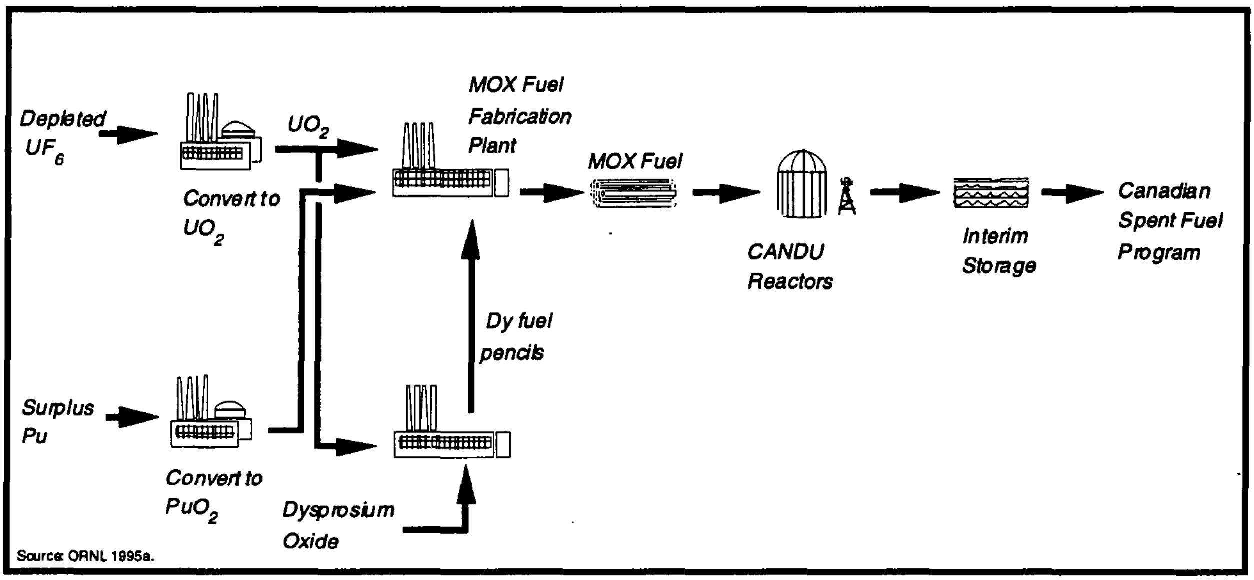

Figure 2.4.5.5–1. Canadian Deuterium Uranium Reactor Mixed Oxide Fuel Cycle.

Construction. The use of MOX fuel in the existing CANDU reactors may require a small addition to reactor site fuel receiving and storage buildings to properly secure the MOX fuel prior to its use. No significant additional land would be required for this construction.

Waste Management. Externally, MOX fuel and natural uranium fuel bundles are identical. The only difference, beside their fuel content, is the higher external radiation level of the MOX fuel bundle. The difference would not result in any increase in the quantity or hazard level of waste produced, processes employed, or facilities required for interim waste storage or disposal.

The Bruce Nuclear Generating Station has facilities for the storage of low-, medium-, and high-level radioactive MOX wastes. Spent MOX fuel bundles would be stored in CANDU wet storage spent fuel modules, equivalent to LWR spent fuel storage racks. Spent MOX fuel decay heat generation and fission product concentration would be similar to current CANDU fuel. The spent fuel resulting from using MOX fuel in the CANDU reactors would be the responsibility of Ontario Hydro and will be stored and disposed of in accordance with procedures established by the Canadian Atomic Energy Control Board.

Transportation. DOE would coordinate the transport of MOX fuel with the Canadian Federal and Provincial Governments. Transportation would be by commercial truck with appropriate security protection, or by SST, in accordance with applicable Federal regulation (49 CFR) and trucking industry practice to ensure safe, secure transport. Fresh MOX fuel bundles would be packaged in a standard stainless steel 208-l (55-gal) container. The packaging would be capable of holding seven CANDU MOX fuel bundles and would have to be certified as Type B packaging and approved for use within both Canada and the United States. The packaging would have to undergo certification by DOE, NRC, and DOT, as well as the Canadian Atomic Energy Control Board and Canadian Ministry of Transport. Although a packaging system has been approved in the United States for shipments of Category 1 materials, it has not yet been approved for the transport of CANDU MOX fuel bundles to Canada.

Based on the annual fuel requirement of 9,052 bundles (ORNL 1995a:26), approximately 54 truckloads per year would be required (slightly more than 1 per week). A brief technical description of MOX fuel use in a CANDU reactor is included in Appendix I.